NAVY EXPERIMENTAL DIVING UNIT

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21	36	Two-Piece Rubber	Wet	27	Uncomfort. cold, wet, numb right hand.
22	35	"	Wet	39	Uncomfort. cold, wet, numb left hand.
23	36	"	Wet	56	Uncomfort. cold, wet, numb hands.
24	35	"	Dry	32	Uncomfort. cold, wet, numb left hand.
25	35	"	Wet	24	Uncomfort. cold, wet, numb hands.
26	37	"	Wet	23	Uncomfort. wet, cold foot due to hole in suit
27	37	"	Wet	21	Diver tore large hole in head of suit
28	36	Standard (Clamp)	Wet	30	Uncomfort. cold, wet, hands
29	35	Two-Piece Rubber	Wet	30	Uncomfort. cold, wet, numb hands.
30	36	Standard (zipper)	Wet	17	Uncomfort. cold, wet, numb hands.
31	35	Two-Piece Rubber	Wet	5	Diver tore large hole in back
32	34	"	Slightly Wet	39	Cold penetrating and starting body chills.
33	34	Standard (Zipper)	Wet	24	Uncomfort. cold, wet, numb left hand
34	35	Two-Piece Rubber	Sl. wet left arm, back	45	Uncomfort. cold, numb left hand, forearm.
35	32.5	Standard (zipper)	Sl. wet	15	Physical discomfort of face mask
36	35	"	Sl. wet	60	Uncomfort. cold toes (dry)
37	36	"	Dry	78	Uncomfort. cold fingers (dry)
38	35	"	Wet	28	Uncomfort. cold, wet, neck, chest, back.
39	35	"	Wet	87	Uncomfort. cold, wet, numb left hand.
40	36	"	Wet	60	Uncomfort. cold, wet, numb left hand.
41	33	"	Wet	74	Uncomfort. cold, wet numb left hand.
42	33	"	Wet	59	Cold, wet legs not covered with polyvinylchoride.
43	33	"	Wet	16	Physical discomfort of face mask

Table #3-B

Unclassified

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13. ABSTRACT

Primarily, in view of the potential use of divers and swimmers in cold water, it is condidered necessary, to develop a means of keeping personnel warm under these condition

DD FORM 1 NOV 65 1473 (PAGE 1)

Unclassified

44	33	Standard (Clamp)	Wet	69	Uncomfort. cold, wet crotch and hands.
45	34	"	Sl. wet	100	Uncomfort. cold, wet, numb hands, urge to urinate
46	34	"	Wet	27	Uncomfort, cold, wet, numb left hand and forearm
47	34	"	Wet	70	Desire to urinate.
48	35	"	Wet	58	Uncomfort. cold, wet, numb hands
49	34	"	Wet	60	Physical discomfort of face mask.
50	35	"	Wet	34	Uncomfort. cold, wet, numb hands.
51	36	"	Wet	50	Uncomfort. cold, wet, numb hands.
52	36	Pirelli	Wet	30	Uncomfort. cold, wet, face chin, neck.
53	37	"	Wet	10	Uncomfort. cold, wet, face chin, neck.
54	37	"	Wet	30	Uncomfort. cold, wet, face chin, neck.
55	37	"	Wet	29	Uncomfort. cold, wet, face chin, neck.

These divers took gloves off underwater to work.
#13 worked for 2 1/2 minutes
#16 worked for 1 1/2 minutes.
#17 worked for 3 minutes.
#20 worked for 30 seconds.

Diver took glove off underwater to work- worked for 58 seconds

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
EDU Protection, Diver, Cold Evaluation, Equipment, Diver						

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PRELIMINARY REPORT ON PROTECTION AGAINST COLD WATER

REPORT NO. 5-52

Depth	Weight required to keep Diver on Bottom (pounds) Chest	Waist	Total on Legs	Total	Weight required for Swimming only Chest	Waist	Total on Legs	Total
Surface (5'water)	13.9	23.3	15.6	52.7	Same as bottom weight.			
10'	8.9	22.2	4.8	35.9	6.5	22.2	4.8	33.5
20'	6.5	22.2	4.8	33.5	Same as bottom weight.			
30'	3.1	22.2	4.8	33.5	3.1	22.2	4.8	30.1
40'	1.7	22.2	4.8	30.1	1.7	22.2	4.8	28.7
50'	1.7	20.8	4.8	27.3	1.7	18.4	4.8	24.9
60'		18.4	4.8	24.9	Same as bottom weight (much air had been used by unit)			
75'		16.0	4.8	20.8		12.0	4.8	16.8
100'		12.0	4.8	16.8	Same as bottom weight.			

Buoyancy of diver wearing 1/4" Button-Stock Suit;1/4" Polyvinylchloride Boots and gloves with two pairs wool sox and one pair wool gloves and watch cap.

Diver used Standard Swim Suit; Pirelli mask and mouthpiece and old type Aqua-Lung.

Table #4

U.S. Navy Experimental Diving Unit
Washington Navy Yard
Washington D. C.

1 June 1952

PRELIMINARY REPORT ON PROTECTION AGAINST COLD WATER

Prepared By

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BUREAU OF SHIPS
Project No. 186-012
Test No. 27

Forwarded by

H. T. FULTON
Officer in Charge

REPORT NO. 5-52

REFER TO: S94/1 (594T), Ser: 594-42 of 28 January 1952.

OBJECTS

Primarily in view of the potential use of divers and swimmers in cold water, it is considered necessary to develop a means of keeping personnel warm under these conditions.

Secondarily to consider the means developed as possible substitutes for the electrically heated underwear in HeO2 diving.

INTRODUCTION

Homeothermic control in man depends upon the balance that the body is able to maintain between heat production and heat loss. (1)

The principals governing the regulating and maintenance of body temperature are well known. Heat production is a chemical process and may be influenced by diet, body build, disease and other factors. Heat loss is a physical and physiological process, and in the normal healthy adult is the more variable.

It is a common experience, for example, that an individual exposed to lowered ambient temperatures can maintain his body temperature at or near normal for short periods of time merely by increased activity. Shivering is an example of an involuntary attempt to achieve this. However, this same individual if exposed for prolonged periods of time even in temperatures as high as 68° F. cannot maintain his thermal balance without some form of protection. (2,5)

This is true of an individual exposed on the surface. The results are even more striking if the person is immersed in water since water has a cooling power some 23 times that of air. The heat loss from an immersed body is almost entirely due to conduction- Convection, (whereas radiation accounts for the greatest heat loss, some 70%, at surface conditions). There will be some elevation in the heat loss due to warming of inspired air, especially in diving operations in cold waters.

The rapidity with which the body loses heat when immersed in cold water will depend primarily on the temperature difference that exists between them. Initially this heat loss will be rapid but it gradually diminishes as the body temperature nears that of its surrounding medium.

The living body acts to retard this heat loss in several ways: (1) redistribution of blood, (2) changes in blood volume, (3) changes in circulatory rate. These several methods are induced by reactions in the autonomic nervous system which responds to changes in blood temperature; to changes in skin temperature; and by responses of vessels to direct stimulation of external temperature changes. (2)

The intial effects of the hypothermia act to produce a peripheral vasoconstriction, and if the exposure be long enough a vasoconstriction involving the extremities and finally the trunk itself. This results in a tissue anoxia which in turn causes an upset in the aerobic phase of heat production in the muscles and finally in the anaerobic phase in the liver. Loss of muscle function follows and thus loss of heat production.

Translating all of the foregoing into practical terms for the diver and underwater swimmer and U.D.T. men, it means that some protective clothing must be developed which will enable the individual to remain immersed in cold waters and still maintain some thermal balance. It must be borne in mind however that such protective gear must not be too cumbersome or too buoyant, and finally, that the added protection it offers is still to be limited by the total exposure time, the temperature of the water and by the possible leakage to be encountered in every diving suit.

PROCEDURE

Initially our investigations started with a diver fully dressed in one of several types of underclothing over which he wore either the U.S. Diver Suit, the Pirelli Suit, or the Standard Swim Suit complete with gloves attached (table 1). Thusly attired he would enter the water and adhere to this schedule: (1) remain at rest until he became uncomfortably cold; (2) after becoming cold, do work equivalent to swimming for periods up to 60 minutes; (3) after work, go back to resting stage and determine how long it takes to become uncomfortably cold again.

Body temperatures were checked before and after each dive and condition of underwear, i.e. wet, dry, was also noted.

This program held true for our first seven dives at which time it was decided to make the remaining dives using detachable gloves. The next six dives were made according to the above schedule, but using detachable gloves.

After 13 dives we changed to the following schedule which used throughout the remaining dives, also using detachable gloves. (1) Diver entered water and did work equivalent to swimming for entire period of dive (2) dive terminated when diver became uncomfortably cold; (3) in five dives diver would remove gloves underwater, while hands were still comfortably warm, and attempt to do delicate-type work using jewelers tools. They would then attempt to put gloves back on and re-warm hands.

A total of 55 dives were made, 19 of which were in water of 40° - 50° F and averaging 45°F; and 36 in water of 32° - 40° F. and averaging 35°F.

Sixteen subjects were used, of whom all but one were experienced divers. (The one exception had never before been in any type of diving suit and he made just one dive).

Endurance runs or "record-setting" dives were discouraged by explaining the importance of the project to all hands, so it is believed that none of these dives were made under either of these conditions.

Thermocouples were not used because of the difficulty involved with the diver being continuously in motion as a swimmer, and also because it was felt that the subjective feelings of the diver were more conclusive than would be thermocouple reading.

All dives were made in one of the pressure tanks at the Experimental Diving Unit with the divers breathing air, except that the dives in the Pirelli Suit were made using the Pirelli self-contained apparatus. No dives were made under any pressure other than the 6 - 7 feet of water in the tank.

TYPES OF PROTECTIVE GEAR EVALUATED

1. U.S. Navy 100% wool diving underwear and 100% wool diving socks.
2. Close-weave nylon underwear and nylon sox made up at this unit using wool underwear as pattern.
3. Combination cotton-wool underwear (outerlayer 40% wool, 60% cotton; inner layer and cuffs 100% cotton).
4. 100% cotton underwear - "Long-Johns".
5. [illegible] 1/8" polyvinylchloride - made up using wool underwear as pattern.
6. Suit of 1/8" polyvinylchloride - with 1/4 polyvinylchloride buttons - made up at this unit.
7. Suit of 1/4" polyvinylchloride - made up at this unit.
8. Suit of 1/4" "Button-stock" polyvinylchloride obtained from U.S. Army.
9. 100% wool mittens - Navy issue.
10. 100% wool "Watch cap" - Navy issue.
11. Surgical rubber gloves.
12. Two compartment mittens (one for thumb, one for other fingers) made up of 1/8" polyvinylchloride backed with same material as U.S. Standard Swim Suit and having elastic wrap-around snappers at cuff.
13. Same as #12 only 1/4" polyvinylchloride.
14. Heavy electrician's rubber gloves fitted with elastic wrap-around snappers at cuff.

All of the above gear was tested either alone or in combination with any other of the listed items. (Table 2).

Polyvinylchloride is supposedly a unicellular material which will not readily absorb water (as will sponge rubber) thereby theoretically retaining its insulative properties.

Differences in manufacture however, exist in the 1/4" material; the 1/8" material and the 1/4" button-stock material (figure 1). The material available for our use consisted of the 1/4" button-stock, smooth on both surfaces; the 1/8" stock not smooth on either surface and 1/4" stock smooth on only one surface.

CONCLUSIONS

A series of 55 divers were made in waters of 40° - 50°F (19 divers) and waters of 32° - 40° F (36 dives). (Tables 3 A-B-C), with divers wearing five different types of swim suits (Table 1) over various types of under wear (table 2), in an effort to develop underwear which would keep a diver warm and comfortable, or at least comfortable, in frigid waters.

As a result of these dives the following conclustions have been drawn.

1. Of all types of underwear tested, the 1/4" polyvinylchloride button-stock worn next to skin gave best results. All twelve divers wearing this underwear remained at least one hour in 32° - 35° water, (except 3 who wore it with Pirelli suit), and remained comfortable in spite of having from 1 to 4 qts. of water inside suit and swim suit. Suit retains its insulative properties since it does not absorb the water. For buoyancy of this suit see Table 4.

2. 1/8" polyvinylochloride either alone or with one suit of cotton underwear beneath it gave results comparable to the 1/4" button-stock when the diver remained dry. Its big fault lies in the fact that it absorbs water thereby decreasing its insulative properies. Wearing this suit, our divers were able to remain on the bottom with 47 pounds of weight. See figure 1.

3. Two suits of woolen underwear is the minimum that can be worn under any swim suit and have the diver remain comfortable in frigid waters. Even if these remain dry, which is unlikely, the intense cold will start to penetrate and produce shaking chills after about 60 minutes in 44° water and 45 minutes in 34° water.

   (a) The wetter they become, through any possible leakage, the shorter will be the dive.
   (b) Wearing this combination, our divers could remain on the bottom with 28 pounds of weight.

4. Three suits of woolen underwear did not give any appreciable increase in duration of dive. Again, the most important factor is how dry the diver remains.

(a) This combination proved to be almost twice as buoyant as the two suits of wool underwear. The divers used 48 pounds of weight to remain on the bottom.

5. No combination of (a) nylon and wools, (b) cotton-wool and wools, or (c) cotton-wools alone gave as good results as did the 2 or 3 sets of wools alone.

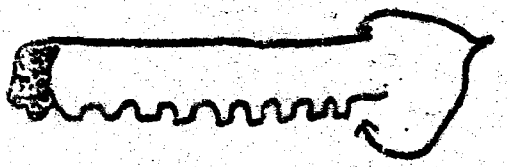
6. It is an established fact that body warmth influences the rate of cooling of the extremities. Even vigorous exercise may have little or no beneficial effect in re-warming an individual's body or extremities or even in retarding the rate of cooling, once the body has been chilled and, or wet. For by this time the individual has already been shivering in a effort to remain warm and he has already raised his heat production to its maximum. (6,7) Coldness, wetness, and numbness of extremities (either hands or feet or both) were the main terminating factors for most dives, especially so when we started using detachable gloves. These problems were overcome however by using 1/4" polyvinylchloride.

(a) Feet remained warm and comfortable in most cases, even though wet when diver wore two pairs wool socks under 1/4" polyvinylchloride boots which would overlap the leg of whatever type underwear was worn. Except in isolated instances, feet ceased to be a terminating reason for any dive when this combination was worn.

(b) Hands remained warm, comfortable and in many cases dry, when diver wore wool gloves under special mitts made of 1/4" polyvinylchloride backed with the same material that standard swim suit is made of. These mitts were fitted with elastic wrap-around snappers at cuff of mitts. Water-tight seal on swim suit was made by using 2" wide metal bands under sleeve of swim suit and then wrapping the snapper of mitt around the metal band to keep all pressure off the arm of the diver. Further facts concerning these mitts are as follows:

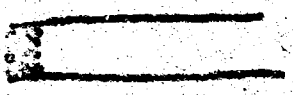
(1) Since we had but one pair of such mitts, and since they were used so often, they developed leaks which eventually could not be patched any more and consequently most divers got their hands wet, cold and numb after about 60 minutes on any dive. With new mitts however and the watertight seal which we would readily effect, the hands also cease to be a terminating reason for any dive.

1/4" Button-Stock

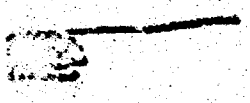


Smooth on both surfaces.
More water-resistant.

1/4" Stock

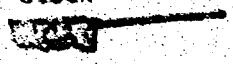


Both surfaces smooth.

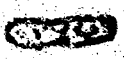


Only one surface smooth.
(Absorbs water)

1/8" Stock



One surface smooth
(Absorbs water)



Neither surface smooth.
(absorbs water readily.

EDGE VIEWS OF DIFFERENT TYPES OF POLYVINYLCHLORIDE

FIGURE 1

(2) These mitts (and polyvinylchloride boots) will dry out completely not matter how wet, in about 15 - 20 minutes by running an air hose up into them. They will also dry in about 60 minutes or less, depending on ambient temperature, by inverting them but this method was undesirable because constant turning inside-out and back again caused cracks in the material mitts were backed with, and resulted in leaks.

(3) These mitts could readily be removed underwater and replaced again by diver but once they were removed and the diver's hands became uncomfortably cold, wet, numb, they were of no value in restoring any warmth to divers hands.

(4) Tables 3-A, 3-C show times divers were able to do effective, delicate-type work underwater once gloves were removed.

7. Head (vertex) and ears which became uncomfortably cold, wet, and numb were found to be terminating or near terminating factors in some dives. We found them to be amply protected by having diver wear standard wool (Navy issue) watch cap under swim suit.

RECOMMENDATIONS

1. Evaluation in the field by underwater swimmers of the protection afforded by polyvinylchloride; its buoyancy and its bulkiness.

2. Restrict, because of its buoyancy (table #4), the use of polyvinylchloride to (1) swimming on the surface; (2) divers, or underwater swimmers, with life line attached to them.

3. Include in the training of underwater swimmers perhaps with redesigned tools, the technique of doing delicate-type work while wearing cumbersome mittens.

4. Evaluate, in the field, the use of polyvinylchloride as a substitute for the electrically heated underwear in HeO2 diving.